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THE QUANTIFIED JUDGEMENT MODEL AND
HISTORIC GROUND COMBAT

by

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This thesis selects for study one particular quantitative methodology called the Quantified Judgement Method of Analysis, or more simply, the Quantified Judgement Model (QJM). The QJM has been used to analyze historic battles and predict future battle outcomes. However, this thesis focuses solely on describing the QJM, analyzing its reasonableness from a military viewpoint, and applying it to historic ground combat. The QJM consists of two submodels whose interactions represent several battlefield intangibles such as leadership, morale, and training. The thesis tests the reasonableness of those submodels and investigates their sensitivity to changes in the model parameters.

Analysis of the model indicates that it is generally sound and reasonable. However, two equations (Combat Power Ratio and Ability to Gain or Hold Ground) were found to be questionable from a military perspective. Further investigations are suggested at the end. Theses. (S[illegible]W)

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The Quantified Judgement Model and Historic Ground Combat

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ABSTRACT

Historic ground combat can be analyzed qualitatively and quantitatively. Qualitative analyses of combat are simply historical accounts or case studies. Quantitative analyses, on the other hand, address the mathematical and statistical aspects of ground combat.

This thesis selects for study one particular quantitative methodology called the Quantified Judgement Method of Analysis, or more simply, the Quantified Judgement Model (QJM). The QJM has been used to analyze historic battles and predict future battle outcomes. However, this thesis focuses solely on describing the QJM, analyzing its reasonableness from a military viewpoint, and applying it to historic ground combat. The QJM consists of two submodels whose interactions represent several battlefield intangibles such as leadership, morale, and training. The thesis tests the reasonableness of those submodels and investigates their sensitivity to changes in the model parameters.

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I. INTRODUCTION

Since the end of the Vietnam War, the United States has been involved in eight military operations involving the use of military force. These operations are the Mayaguez Rescue (1975), Iran Rescue Mission (1980), Beirut Peacekeeping Force (1982 - 1984), Grenada Operation (1983), Bekaa Valley Air Raid (1984), F-14 Shootdown of two Libyan Aircraft (1984), Libyan Air Raid (1986) and Persian Gulf Reflagging Presence (1987- Present). Of these operations, at least five (Mayaguez, Iran Rescue, Beirut Peacekeeping, Grenada and Bekaa Valley) have been categorized as either being poorly planned or executed. For each unsuccessful operation, criticism of U.S. military operational competence by members of Congress and private organizations (such as the Military Reform Institute and segments of the media) became louder and more frequent. By the mid 1980's the issue of "military reform" was gaining increased attention in government, academic, and private circles. In his 1984 book, *The Pentagon and the Art of War*, the controversial strategist Dr. Edward Luttwak paints a bleak picture of U.S. military operational competence [Ref. 1: p. 23]. He states:

> The peacetime defects of the military establishment and its failure in war are closely connected, and the causes of both are best revealed by a review of the painful record of Vietnam. A reluctance to look back upon defeat is quite normal but also most dangerous, for it leaves unexamined fatal defects of structure and system that still endure. Much of what went wrong in Vietnam belonged to the time and place, but much resulted from military institutions that remain unreformed; and which failed again in the Iran raid, Beirut, and Grenada; and which continue to fail in converting manpower and money into effective military power.

Are the criticisms levied by Dr. Luttwak valid? Has he and those who share his views forgotten the human and material costs typically associated with armed conflicts? Clearly, many Americans expect U.S. military operations to be routinely swift, lethal, totally successful and with minimal U.S. personnel and equipment losses. But these are merely expectations and the reality of combat is usually quite different.

This thesis arises from a personal interest in how the U.S. military evaluates its own and other nations' combat performance. Exploratory studies have revealed the existence of numerous techniques or methodologies for analyzing land combat. These methodologies seem to fall into two major categories. The first category encompasses historical studies which are simply narrative accounts of combat. These accounts are the

standard military historical publications found in libraries and bookstores, and they are qualitative in nature. The second category focuses on analytical techniques which attempt to quantify armed conflict. These techniques can range from simple statistical comparisons to highly complex computer simulations of combat models.

Initially, the intent of the thesis was to analyze the U.S. military invasion of Grenada (Operation Urgent Fury) through one particular methodology in the second category called the Quantified Judgement Method of Analysis, or more simply, the Quantified Judgement Model (QJM). The objective of the thesis was to see if the QJM adequately and accurately described Operation Urgent Fury. Additionally, we wanted to explore the sensitivity of the model to changes in such parameters as number of weapon systems, terrain, weather, and strength of the enemy.

Since the QJM was published in military Operations Research literature and used to describe well over 200 historic battles, we assumed the model to be valid. In other words, we expected the main QJM equations and factors to be mathematically sound. We soon found out, however, that our assumption of a flawless model was incorrect. Eventually, the focus of the thesis shifted from applying the model to an actual battle (Urgent Fury) to examining the model solely for reasonableness. Our objective now was to determine if the QJM equations, submodels, and factors made sense from a military perspective, and if they did not make sense to explain why and offer recommendations.

The QJM is used to examine past battles as well as predict future battle outcomes. However, the thesis focuses exclusively on describing the QJM and applying it to historic ground combat. The QJM analyzes historic combat and evaluates opponents in terms of relative combat power and relative combat effectiveness. It is composed of two submodels whose interactions manifest such battlefield intangibles as leadership, morale, training, and so forth. The thesis tests the reasonableness of those models and investigates their sensitivity to changes in the model parameters.

The thesis is organized into five chapters. Following the Introduction (Chapter 1), Chapter 2 describes qualitative and quantitative methodologies for analyzing ground combat. The methodologies are explained and their respective strengths and weaknesses are cited. Chapters 3 and 4 address the Quantified Judgement Model and its application to ground combat. The QJM is introduced (development history), defined, and decomposed. Its submodels are analyzed through numerous examples to increase understanding of the model, to provide insight into combat dynamics, and to test the reasonableness of the submodels. The objective of these chapters is to determine if the

QJM is reasonable and if it adequately and accurately portrays ground combat. The final chapter (Chapter 5) summarizes the thesis and suggests areas of the QJM requiring further study.

II. ANALYZING LAND COMBAT: QUALITATIVE AND QUANTITATIVE METHODOLOGIES

A. INTRODUCTION

Can meaningful lessons be drawn from studying past wars? If so, can those lessons be applied to present day military forces to ensure a greater likelihood of success on the battlefield? This chapter presents a brief overview of methodologies used by military and civilian analysts in reaching fairly accurate and useful conclusions about war.

The history of humankind is replete with examples in which superior military forces have defeated, or been defeated by, supposedly inferior opponents. The U.S. invasion of Grenada in order to rescue U.S. citizens and neutralize a hostile government is an example of a superior force defeating its opponent. Certainly the massive array of military forces available to U.S. planners against a relatively small Cuban force guaranteed success. On the other hand, Soviet forces in Afghanistan, clearly possessing superiority in firepower, mobility, and trained personnel over their opponents the Mujahidin, are no closer to a military solution than they were in 1980. The American experience in Southeast Asia provides a close parallel to the present Soviet situation in Afghanistan.

What can be learned from studying war and how can the findings be applied to military forces? For centuries, military historians and strategists have grappled with this issue. Some, such as Clausewitz, have developed their theories on war from studying modern history [Ref. 2]. Others have focused their analysis on specific aspects of a military campaign (such as, tactics, logistics, and mobility). Since World War II, the military analyst has increasingly exploited computers and mathematical techniques to identify and dissect the components of warfare. The results of these analyses of past wars, whether arising from either historical analyses, case studies, computer simulations, or mathematical relationships, are commonly referred to as *lessons*. But what exactly is a military lesson? Do we study a specific conflict and then select that particular strategy, tactic, or piece of equipment which appeared pivotal in the battle's outcome? Likewise, once we have identified that variable, can we infer that its proper application in a future war will ensure victory?

The goal of this chapter is not to present a checklist for finding military lessons, but to explore methodologies that have been used in analyzing war.

B. QUALITATIVE ANALYSES: HISTORICAL ACCOUNTS AND CASE STUDIES

Throughout recorded history, past wars have been studied in order to see how to gain an advantage over an opponent. Given the technological nature of modern society, are the analyses of past wars really of any value in developing more effective combat forces? Can new doctrine, strategy, and tactics be validated by examining previous wars? Or must we simply rely on actual present or future combat to establish their validity? There exists a voluminous body of work on many great generals (such as Alexander, Hannibal, Caesar, and Napoleon) and their campaigns. Certainly any military person or historian can learn about grand strategy, leadership, and innovation from these masters. Yet, a direct application of the ideas of these masters to the present day, in terms of pure strategy and tactics, is tenuous. More likely, it is the wars of recent history which may have the most to tell us. In the context of this discussion, *recent* shall mean from World War II to the present. For the most part, recent wars are still closely linked to the present by political, strategic, tactical, and technological channels. Napoleon, knowing that his own officers lacked knowledge concerning wars recent to his times once remarked, "All of our young men find it easier to learn about the Punic Wars than the War of the American Revolution."[Ref. 3: p. 57]

By comparison, following World War I the German Army closely examined its performance during that war to seek improvements in its doctrine and training [Ref. 3: p. 63]. Initial German successes in World War II can be attributed to a General Staff which provided the structure and leadership to implement strategically what had been learned from the World War I combat lessons.

If meaningful lessons are to be learned from studying past wars, how does the military analyst or historian uncover them? In the first place, each analyst has his or her own experience level, coupled with personal and professional biases. For instance, an infantry officer may draw quite different conclusions from examining a battle site than would a combat engineer. It is important for each analyst to see and acknowledge that he or she views the world according to personal experiences and biases. That is, each person has a particular and unique frame of reference. As history shows, bias (whether institutional or personal) often contributes to the disregard and underestimation of an opponent. In 1939, the French High Command discounted Germany's effectiveness in driving through Poland and held firmly to the belief that what occurred there could not happen in France because, "We are not Poles." [Ref. 3: p. 64]

More recently, Halberstam [Ref. 4] portrays Lyndon Johnson and his advisors as grossly underestimating both North Vietnam's commitment to fight, and its effectiveness as a military force, early on in the Vietnam conflict.

Another way combat lessons sometimes go undetected is when a tunnel vision effect occurs on doctrine. As an illustration, note that most conflicts in the last 15 to 20 years have been of low intensity and have occurred in the Third World. If increasing low intensity warfare is indeed a trend, then gross overemphasis on conventional warfighting doctrine (in a European scenario) may be unjustified. The military analyst must not allow his particular service doctrine (e.g., U.S. Army: Airland, USMC: Amphibious) to act as blinders to warfare trends. Without question, doctrine is paramount to today's modern armies. It shapes force structure and defines budgetary requirements. Nevertheless, it can stifle the generation and promulgation of new ideas. After World War I, the French were so enamored of their defensive doctrine that they failed to heed dramatic German successes in Poland in 1939. As shown by history, doctrine should never drive the scope and substance of military lessons to be learned. Rather, sound and unbiased analyses of past wars, and their associated lessons, should drive the evolution of doctrine. The reality that doctrine has determined which lessons to draw is illustrated by this excerpt [Ref. 5: pp. 338-343] from the British Official History of the Russo-Japanese War:

> If the comments in the Official History are to have any value for the Army, they must be in consonance with the doctrine of war which the General Staff is teaching.

Besides excessive reliance on doctrine, valuable combat lessons may also go unheeded when military analysts/observers are overdirected in the areas from which to seek lessons. Military analysts/observers are most effective when they are free to observe and question any important aspect of the war, according to their experience and judgement.

If we assume that an unbiased analysis has been conducted on a recent war and that valuable lessons have been obtained, how can that information be translated into improved combat effectiveness? Granted, the combat analysis itself has yielded important lessons, but they are valueless unless converted into the currency of wartime effectiveness. To illuminate this idea, note the case of Military After Action Reports. These reports are produced at the conclusion of exercises and operations, and generally contain a section on lessons learned. Over time, After Action Reports accumulate in the files and safes at higher headquarters, often not reviewed until just prior to the next

iteration of the exercise, or when periodic crises erupt in a particular country. The mere production and aggregation of lists of lessons learned provide little, if any, benefit to combat forces. To be of value, a mechanism must be in place to take those lessons, conduct analyses and integration of them, and translate them into effective action. Finally, the lessons learned must be disseminated down to the fighting forces in the forms of doctrine and training.

Most military men acknowledge that there is no better way to develop combat proficiency than through personal combat experience. However, combat experience is a commodity in short supply for the armed forces during prolonged periods of peace. As a result, the development of doctrine and training from studying the lessons of recent wars and potential adversaries yields the next best means of improving combat effectiveness. As early as 1966, the U.S. Army required commanders to include a section on lessons learned in combat in their After Action Reports [Ref. 6]. From what is now known about the outcome of the Vietnam War, the question must be raised as to why our lessons learned were not more decisive in determining the outcome of the war. Did political and military institutions, as well as their huge bureaucracies, prevent the implementation of the appropriate lessons? Or were decisions makers operating under a flawed set of assumptions concerning our opponent?

Nongovernment organizations, such as RAND or other research groups, are equally vulnerable to reaching faulty conclusions from the study of war. However, the causes of flawed analysis in the private sector seem to stem from other factors. Private organizations are frequently constrained to publish studies in an unclassified form. Consequently, they depend on unclassified and second-hand sources of information. The scarcity of accurate unclassified combat data, combined with the possibility of misinformation, may lead to analysis of questionable accuracy and depth. The Military Reform Institutes, *Grenada Operation Report* of 5 April 1984, reviewed five major aspects of the operation and was given substantial coverage by the media. The Report's total length was a mere four and one-half pages; clearing raising a question of analytical depth and thoroughness.

Historically, it seems clear that successful military forces do act upon their lessons learned. Moreover, military structure and bureaucracy are not so rigid as to suppress original ideas. The historical analysis of recent wars, military operations, and exercises can provide a means to improve combat effectiveness through the development of appropriate doctrine, strategy, or tactics. Quite likely, the thorough analysis of one

conflict is preferable to a shallow study of several conflicts, each touched upon only briefly. In the words of Clausewitz [Ref. 2: p. 173],

> Where a new or debatable point of view is concerned, a single thoroughly detailed event is more instructive than ten only touched upon.

If several distinct conflicts are to be studied, then caution should be exercised in making across-the-board comparisons. Each war or battle is unique in the way its variables (e.g., opposing forces, terrain, weather, leadership, morale, etc.) interact to produce the final outcome. Attempted linkage of different wars' lessons is risky. Additionally, established doctrine should not constrain the conclusions of the analysis. Meaningful lessons of war stand on their own merits and need not be supported by doctrine to justify their validity.

The modern military historian Luvaas [Ref. 3: p. 69] asserts that historical analysis should seek understanding and not pat answers:

> Insights gained would be a more appropriate concept. Frederick The Great, Napoleon, and Clausewitz would clearly have understood that. Their observations, albeit in a far simpler world, led in most instances to profound understanding, and that is precisely the dimension lacking in our current approach to many situations.

C. QUANTITATIVE ANALYSES

In the previous section, the approaches of historical analyses and case studies were examined as potential descriptive methodologies for evaluating war. This section focuses on drawing military lessons from quantitative analyses.

To establish a framework for discussion, it is desirable to separate warfare quantitative analyses into macrolevel and microlevel categories.[1] Of the two categories, the macrolevel is the most straightforward and least controversial. By examining recent wars at the macrolevel, a military analyst establishes a baseline on which to build the analysis. For instance, the media, politicians and elected officials routinely state that the world is becoming increasingly dangerous. In an attempt to address this assumption, the following macrolevel analysis from the *Journal of Peace Research* is offered [Ref. 3: p. 43]:

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1 Harkavy in [Ref. 3: p. 5] discusses conceptual and methodological issues in studying war and introduces the terms macrolevel and microlevel.

TIME PERIOD	AVERAGE NUMBER OF ARMED CONFLICTS
1945 - 1948	6.3
1949 - 1952	6.6
1953 - 1956	8.3
1957 - 1960	9.6
1961 - 1964	13.3
1965 - 1968	20.1
1969 - 1972	17.1
1973 - 1976	11.1

Figure 1. Average Number of Armed Conflicts per Year

Though the data ends with the period 1973-1976, we observe that there is a trend in the number of wars over time, but not necessarily an increasing one. It would be interesting to see what the numbers look like from 1977 onward, and if any further insights could be gained. This category of analysis does a superb job of taking an ill-defined assumption (such as, the world is increasingly dangerous) and making it more clearly defined. Most importantly, analysis of this type may actually disprove underlying initial assumptions.

One question to raise concerning the data in Figure 1 is the definition of *armed conflict.* Conventional interstate wars such as Iran-Iraq and the Falklands are bonifide armed conflicts, but insurgencies in Sri Lanka and Angola are less easily classified. Furthermore, how small does an armed conflict have to be before it is viewed as just a police action or random act of violence (and not a *war* at all). In other words, strict definitions must be made and adhered to in macrolevel analysis. Precise definitions allow both the analyst and the recipient of the analysis to adhere to a common frame of reference, reach common conclusions, and thus communicate more effectively.

A second example of macrolevel analysis is provided in Figure 2, where terrorist incidents are categorized according to time frame and geographic region [Ref. 3: p. 45].

GEOGRAPHIC REGION	NUMBER OF INCIDENTS
Atlantic Community	572
Middle East	159
Asia	102
East Europe	8
Latin America	282
Africa	37

Figure 2. Distribution of Terrorist Incidents, 1968 - 1975

Figure 2 provides a concise breakdown of terrorist incidents worldwide. The analysis reveals that most terrorist incidents in the eight year span occurred in the Atlantic Community and Latin America. Again, the data raises at least two interesting questions.

1. How is the term *terrorist incident* defined ? A precise definition of terrorist incident in terms of the analysis removes any doubt as to how incidents are defined.
2. What are the sources of information used to derive the analysis ? Open societies are more apt to report terrorist incidents than communist regimes and dictatorships. Therefore, the data may not reflect real events.

Do macrolevel analyses yield valuable military lessons? Can knowledge of the trends in recent warfare benefit those who make decisions regarding U.S. military force structure? Obviously the armed forces of a nation should be developed and maintained to handle effectively the range of potential threats which it must face. So if macrolevel analysis of recent wars points to an increase in Third World revolutionary war, then we should acknowledge that fact when we create forces and doctrine. Failure to study trends in warfare, combined with a view that wars which we are unaccustomed to fighting are somehow less significant, may yield ineffective results on the battlefield. As the French and Americans both found out in Indochina (and as the Soviets have found in Afghanistan), the types of warfare which countries are ill-prepared to wage possess valuable lessons to be studied. Of course major powers, by nature of their worldwide commitments, are unable to focus exclusively on small conflicts. As the French, Americans, and Soviets found out, their opponents had the luxury of total commitment to the conflict while they did not.

The above discussion on French, American, and Soviet combat experience demonstrates why a clear understanding of worldwide trends in armed conflict by top military and government leaders is critical to ensuring that U.S. force structure and doctrine reflects today's military challenges and political realities.

Macrolevel analyses illuminate trends in warfare, whereas microlevel analyses focus on specific combat scenarios. Microlevel analyses are more difficult to produce than those at the macrolevel, and often their conclusions are more difficult to interpret. However, the numerous commitments which U.S. military forces must uphold, and their associated range of responses, mandate that potential combat scenarios and proposed weapon systems be studied extensively.

The realm of technical microlevel combat analysis is relegated to professional military and civilian Operations Research analysts. These analysts have at their disposal a myriad of analytical resources. Even with such an impressive inventory of computing tools, analysts can neither predict future battle outcomes with absolute certainty nor simulate past battles exactly the way they actually occurred. Yet, microlevel analyses still represent one of the most powerful approaches to evaluating combat lessons.

For instance, computer simulations of a piece of military hardware (e.g., flight of a tank round) can often be as accurate, and even cheaper, than actual field tests. At lower levels of resolution, combat engagements, up to the battalion level, are frequently simulated to examine the effects of weapon performance and tactics. As a computer simulation becomes more complex (by either certain probabilistic factors or the inclusion of additional input variables) it generally becomes more difficult to validate the results or conclusions. In some simulations, validation can be achieved by making comparisons between historical combat results or actual field data. However, all complex aggregated simulations (such as, determining the winning side in a theater level war) are difficult to validate.

There are specific variables of war which are difficult or impossible to measure yet have a decisive affect on battle outcomes. Three of these variables are leadership, training, and morale. Operations Researchers are presently divided on whether variables of this type should be included in their analyses. Furthermore, if a consensus is reached on incorporating these intangibles, the question still remains as to how to best represent them. Such terms as *well trained* and *completely surprised* are usually ill-defined and highly individualized judgements. Nevertheless, research does continue on the

incorporation and quantification of these difficult to measure, but highly important, variables of war.

Quantitative methodologies can be applied to uncover lessons in past wars or to test lessons in future wartime scenarios. On the macrolevel, trends in the type, duration frequency, and location of wars can be discovered and used to our advantage. Macrolevel analyses often require only the most basic mathematical skill to apply. On the other hand, real skill is required in asking *the right* pertinent questions and in adhering to established definitions. Trends in warfare do actually occur, and they must be made known to top level decision makers.

Detailed or microlevel analyses of strategy, tactics, and weapons can be performed by computer simulations or through mathematical models such as the Lanchester differential equations. The interpretations and conclusions of these analyses are typically highly specific (such as, the average number of enemy casualties or tank rounds expended). It is important to realize that it is usually impossible for a simulation to include every variable of a past or (hypothetical) future battle. Nevertheless, computer simulations and mathematical models are important analytical tools. Individual hardware performance can be simulated rather effectively. Battalion and lower level engagements with representations of terrain, mobility, target detection and weapon effects can be simulated, and the computer programs run repeatedly in order to obtain reliable output values. Macro and microlevel quantitative analyses can be valuable tools for revealing some of the hidden lessons of war.

D. SUMMARY

Warfare can be studied from both historical and analytical standpoints. Each vantage has the potential to yield select combat lessons which, if properly exploited, promise to enhance combat performance.

Historical analyses are not a panacea for battlefield success because the issue of historical analysis centers on prudency. Richard Betts in *Soldiers, Statesmen and Cold War Crises* writes:

> Trying to use the lessons of the past correctly poses two dilemmas. One is a problem of balance: knowing how much to rely on the past as a guide and how much to ignore it. The other is a problem of selection: certain lessons drawn from experience contradict others.

For this reason, superior combat forces have been those best able to achieve this balance by selectively drawing lessons from their own and other's combat experiences. Likewise,

excellence in exploiting combat lessons does not imply the exclusive study of positive lessons; that is, the actions taken by the victorious force. Positive lessons of past campaigns do not guarantee present day victory. Frederick the Great of Prussia learned in his first battle not to rely on a tactic or strategy simply because it worked somewhere else. According to Luvaas [Ref. 3: p. 56],

> Frederick had endeavored to offset his own inferiority in cavalry by placing two battalions of grenadiers between the cavalry squadrons of each wing. "This was the disposition made by Gustavus Adolphus at the battle of Lutzen," he explained...noting that "according to all appearances," this particular tactic "will never more be practiced."

Quite possibly, the negative lessons of war (that is, the actions taken by the defeated force) may be more instructive. Frequently, it is the defeat in battle which causes a strict examination of the factors which led to that defeat. The huge amount of literature on the Vietnam War can likely be attributed to our unsuccessful efforts there [Ref. 7 : pp. 19-31]. Self examination of combat failures, has been shown to contribute to improved performance in a future war. Following World War I, the Germans analyzed their wartime performance and took subsequent action to improve military doctrine and training. Their early successes in World War II demonstrated the degree to which they had assimilated the lessons from their World War I experiences.

In searching out combat lessons military analysts must not allow personal and professional biases to prejudice their findings. Viewing the battlefield environment through the frame of a rigid doctrine allows many crucial lessons to slip past scrutiny. Combat lessons should themselves drive the examination of existing doctrine or the development of new doctrine. Useful combat lessons can then be converted to some coherent part of doctrine. An implementation process, unhampered by bureaucratic entropy, then needs to be in place to analyze, integrate, and disseminate the lessons learned to combat forces by way of appropriate doctrine and training. As the combat environment becomes more sophisticated and competitive, the successful military organizations will be able to exploit rapidly the combat lessons of past battles.

Quantitative analyses of war differ from historical analyses by focusing on the mathematical and statistical aspects of the conflicts. Quantitative analyses can be simple or complex; the number of ongoing wars in a particular region is simple compared to the complexity of a computer simulation of theater-level war. In any case, quantitative analyses provide a wide range of information and insight into war. Quantitative measures are capable of identifying trends in war, providing test criteria of weapon

systems according to established tactics, training personnel under simulated combat conditions, and validating combat lessons under various wartime scenarios. The fact that simplifying assumptions are incorporated into every quantitative analysis, as well as the acknowledgement that every factor cannot be accounted for in the model, underscores the realization that analyses of this type are not absolutely correct. They are approximations to reality. Nevertheless, if used selectively and intelligently, quantitative methods can contribute to improved force effectiveness.

Are qualitative and quantitative analyses equally proficient methods to identifying combat lessons, or is one approach superior to the other? There is no simple answer to this question. However, knowledge of, and exposure to, both methodologies enable an analyst to be more resourceful and effective in studying war. The ability of the military analyst to bring both methodologies to bear on the study of a past conflict unequivocally contributes to sounder analysis. The challenge lies in convincing both military analysts and combat leaders that the study of war is neither easy nor simply a matter of compiling checklists. It is by applying the select lessons of history and precise analytical skills that the true nature of combat can be revealed.

In the next three chapters, a specific method of analysis known as the Quantified Judgement Model, is presented. The Quantified Judgement Model will be described and analyzed in the context of exploring historic ground combat. The objective of the ensuing three chapters is to determine if the model is reasonable and if it accurately and adequately represents historic ground combat.

III. HISTORICAL GROUND COMBAT AND THE QUANTIFIED JUDGEMENT MODEL

A. INTRODUCTION

In the previous chapter, various methodologies for analyzing land combat were explored. In this chapter, the Quantified Judgement Model (QJM) is introduced, described, and illuminated through examples. The goal of the chapter is to determine if the model is reasonable and the extent to which it adequately and accurately represents historical ground combat. Though the QJM may be used to predict future battle outcomes, the next two chapters focus exclusively on historical combat and the QJM.

The QJM was developed by Col. T.N. Dupuy U.S. Army, Ret. in association with colleagues from the Historical Evaluation and Research Organization. Dupuy, an eminent military historian, has taken Clausewitz's masterwork *On War* and applied analytical and mathematical refinement to Clausewitz's theory. Dupuy cites passages in Book Three, Chapter 8 of *On War* and terms them "Clausewitz's Law of Numbers." He postulates that this "Law of Numbers" represents an expression equating the combat power of a force to be the product of the number of its troops times an environmental/operational factor times a quality of troops factor (Figure 3).

In the 150 years since Clausewitz's death, weapons have changed radically in terms of lethality, range, means of delivery and mobility. To account for weapon evolution, Dupuy replaces the number of troops factor with force strength and defines it as a force's total inventory in weapons (number and type) and personnel. His interpretation of Clausewitz's theory is represented mathematically in the following figure.[2]

2 Notational differences exist between the thesis and [Refs. 8, 9]. For instance, Dupuy defines operational/environmental factors with V whereas the thesis uses the symbol OE. Notational changes are used to reflect better the meaning of the terms to enhance the understanding by the reader.

$$P = S \times OE \times Q$$

where:

P = combat power of the force

S = force strength (number and type of weapons plus personnel)

OE = operational/environmental factors

Q = quality of troops

Figure 3. Combat Power Equation

Notice that combat power (P) is equal to the product of three factors. Why are the factors multiplied and not added? Clausewitz's writings suggest that combat power (P) is proportional to force strength (S) [Ref. 8: p. 28]. If this is the case, then the proportionality factor may be interpreted as the constant $OE \times Q$. As either factor (OE or Q) decreases, so does combat power even though the force strength (S) itself remains constant. Likewise, if either factor increases (and S remains constant), the combat power increases. Of course a reduction in S also reduces P.

The combat power factors S, OE, and Q are derived from equations introduced and described in Chapter 4. Figure 4 provides value (real or integer) and approximate range data for the factors.[3]

FACTOR	VALUE	APPROXIMATE RANGE
S (force strength)	real	500 to 500,000
OE (operational/environmental)	real	0.25 to 4.0
Q (troop quality)	real	0.20 to 5.0

Figure 4. Range of Combat Power Factors

Dupuy reasons that if the combat power of a single force can be computed, then similar calculations can be performed for two forces engaged in combat. Moreover, a *relative combat power* of opposing forces may be calculated by taking a ratio of the

[3] The range of values for S, OE, and Q in Figure 4 are highly approximate and obtained from [Ref. 8: pp. 82,83] and [Ref. 9: pp. 228-230,234-239]. Theoretically, force strength (S) can range from zero to infinity. However, Figure 4 uses arbitrary S values of 500 to 500,000.

forces' combat power values. That is, if P(b) is the combat power of the blue force, and P(r) the combat power of the red force, then the ratio P(b) P(r) represents the relative combat power of the blue force to the red force. This ratio is designated the **Combat Power Ratio.** The following three examples illustrate the utility of the combat power ratio for opposing red and blue forces.

<u>Example 1</u>

FACTOR	RED FORCE	BLUE FORCE
Force Strength (S)	1000	500
Operational/Environmental (OE)	1.0	1.0
Troop Quality (Q)	5.0	5.0

The Combat Power Ratios are:

$$\frac{P(r)}{P(b)} = \frac{1000 \times 1.0 \times 5.0}{500 \times 1.0 \times 5.0} = 2$$

and

$$\frac{P(b)}{P(r)} = \frac{500 \times 1.0 \times 5.0}{1000 \times 1.0 \times 5.0} = .5$$

Discussion: Both forces are evenly matched in operational and environmental and troop quality factors. However, the Red force possesses twice the force strength as blue resulting in a combat power advantage for the red side.

Example 2

FACTOR	RED FORCE	BLUE FORCE
S	1000	500
OE	1.0	1.0
Q	1.0	3.0

The Combat Power Ratios are:

$$\frac{P(r)}{P(b)} = \frac{1000 \times 1.0 \times 1.0}{500 \times 1.0 \times 3.0} = .666$$

and

$$\frac{P(b)}{P(r)} = \frac{500 \times 1.0 \times 3.0}{1000 \times 1.0 \times 1.0} = 1.5$$

Discussion: The operational/environmental factors for each side are identical. Therefore, these factors do not contribute to a combat power advantage for either side. Though the red force commands a two to one strength edge, we see that the blue force's troop quality advantage is even greater. Taking these factors into consideration, overall red force combat power is less than that of the blue force. Clearly, the superior quality of blue troops offsets the strength superiority of the red force.

Example 3

FACTOR	RED FORCE	BLUE FORCE
S	1500	500
OE	1.0	2.5
Q	2.0	1.5

The Combat Power Ratios are:

$$\frac{P(r)}{P(b)} = \frac{1500 \times 1.0 \times 2.0}{500 \times 2.5 \times 1.5} = 1.6$$

and

$$\frac{P(b)}{P(r)} = \frac{500 \times 250 \times 150}{1500 \times 100 \times 200} = .625$$

Discussion: In this example, a vastly superior red force attacks a blue force established in defensive positions. Because of its defensive posture, the blue force maintains a powerful advantage in operational and environmental factors. However, the red force is both superbly trained and well lead; two ingredients which contribute to its high troop quality value. Taking all three factors into consideration, the red force is more combat powerful than its blue adversary.

The preceding examples illustrate the employment and meaning of the QJM combat power ratio. In Chapter 4, an examination is made of how the QJM assigns values to force strength (S), operational environmental factors (OE), and troop quality (Q).

Dupuy's efforts to lend quantitative weight to Clausewitz's theory led to the formulation of a Combat Power equation to compute a force's historical combat power. To compare the equation's results to actual history, Dupuy employs a second equation which quantifies historical battle outcomes. This equation asserts that a force's outcome in battle is equal to the sum of three factors: mission accomplishment, ability to gain or hold ground, and force effectiveness when casualties are incurred. Stated mathematically, the equation is expressed as:

$$R = M + G + C$$

where:

R = battle results of the force

M = mission accomplishment

G = ability to gain or hold ground

C = effectiveness when casualties are incurred

Figure 5. Actual Battle Results Equation

Unlike the Combat Power equation, the Actual Battle Results equation consists of three terms added together. Why does the QJM sum the terms M, G, and C? A possible explanation is that if one of the terms is small, say effectiveness when casualties occur C, the value of R can still be significant if M and G compensate enough for the smallness of C. The terms M, G, and C are also dimensionless quantities, which will be seen later in the thesis.

The factors G and C are derived from equations introduced and described in Chapter 4. Mission accomplishment (M) values are obtained from Figure 22 in Chapter 4. The actual battle results factors (R, M, G, and C) occur in the following values and approximate ranges:[4]

FACTOR	VALUE	APPROXIMATE RANGE
R (actual battle results)	real	-5.5 to 16.5
M (mission accomplishment)	integer	1 to 10
G (ability to gain or hold ground)	real	-3.0 to 3.0
C (casualty effectiveness)	real	-3.5 to 3.5

Figure 6. Range of Actual Battle Results Factors

Actual battle results for opposing forces in historic combat are calculated individually using the equation $R = M + G + C$. The values for two opposing forces are

4 The range of values for R, G, and C in Figure 6 are only approximate and were generously provided by T. N. Dupuy in a private communication.

expressed as a ratio R(b):R(r) which Dupuy designates the **Results Ratio.** The operation of the results ratio is demonstrated in the ensuing two examples.

Example 4

FACTOR	RED FORCE	BLUE FORCE
Mission Accomplishment (M)	8	2
Ability to Gain or Hold Ground (G)	2.0	1.0
Effectiveness when Casualties are Incurred (C)	1.0	1.5

The Results Ratios are:

$$\frac{R(r)}{R(b)} = \frac{8 + 2.0 + 1.0}{2 + 1.0 + 1.5} = 2.44$$

and

$$\frac{R(b)}{R(r)} = \frac{2 + 1.0 + 1.5}{8 + 2.0 + 1.0} = .41$$

Discussion: The red force was overwhelmingly successful in executing its mission, while the blue force was not. Furthermore, it was twice as successful as blue in gaining or holding ground. Though the blue force was more effective in fighting with casualties, this advantage could not offset the red force's superiority in the two other factors. For this battle, the red force was the clear winner.

Example 5

FACTOR	RED FORCE	BLUE FORCE
M	5	5
G	3.0	1.0
C	1.5	2.0

The Results Ratios are:

$$\frac{R(r)}{R(b)} = \frac{5 + 3.0 + 1.5}{5 + 1.0 + 2.0} = 1.19$$

and

$$\frac{R(b)}{R(r)} = \frac{5 + 1.0 + 2.0}{5 + 3.0 + 1.5} = .84$$

Discussion: In this example, each force accomplished its assigned mission in a less than satisfactory manner. However, the red force was far more capable than blue in either gaining or holding ground, even though blue was slightly more efficient in operating with casualties. Taking all three factors into account, the results ratio indicates that the red force won.

Later in the thesis, we explore how the QJM assigns values to mission accomplishment (M), ability to gain or hold ground (G), and effectiveness when casualties are incurred (C).

1. Section Summary

The QJM employs two separate submodels to evaluate historic ground combat. The Combat Power equation yields a force's historical combat power and is used to obtain a combat power ratio for opposing forces. The Actual Battle Results equation calculates how well an individual force performed in combat and is used to compute a results ratio for opposing forces. In Section B, the combat power and results ratios are used to obtain an expression for a force's combat effectiveness. The combat effectiveness expression is analyzed both for reasonableness and for its potential in providing insight into ground combat.

B. MODEL DESCRIPTION

Recall that the Quantified Judgement Model uses two submodels to evaluate historic ground combat:

Combat Power Equation: $P = S \times OE \times Q$

where:

P = combat power of the force
S = force strength (number and type of weapons plus personnel)
OE = operational/environmental factors
Q = quality of troops

and

Actual Battle Results Equation: $R = M + G + C$

where:

R = battle results of the force
M = mission accomplishment
G = ability to gain or hold ground
C = effectiveness when casualties are incurred

Figure 7. QJM Submodels

In analyzing opposing forces relative to one another, the models are used to give ratios. Using the example of blue (b) and red (r) adversaries the ratios are:

Combat Power Ratio $\equiv \dfrac{P(b)}{P(r)}$

and

Results Ratio $\equiv \dfrac{R(b)}{R(r)}$

Figure 8. Combat Power and Results Ratios

These ratios allow historical combat to be analyzed both descriptively and theoretically. As discussed, *the results ratio describes historical battle outcomes* and can be thought of as a report card which grades opponents in terms of mission accomplishment, ability to gain or hold ground, and effectiveness when casualities are incurred. To evaluate the engagement theoretically, QJM's developers redefine the combat power ratio, omitting each sides troop quality (Q) term , to depict theoretical battle outcomes. Put more simply, theoretical outcomes reflect a victor's superiority in numbers of personnel, weapons, and operational/environmental factors. This relationship, termed Theoretical Combat Power (P′), is defined as follows:

Theoretical Combat Power (P′) $P' = S \times OE$

Using blue and red forces, if R(b) and R(r) represent actual battle results and P′(b) and P′(r) theoretical combat power *sans* respective troop quality factors, then we define:

Theoretical Combat Power Ratio $\equiv \dfrac{P'(b)}{P'(r)}$

and

Actual Battle Results Ratio $\equiv \dfrac{R(b)}{R(r)}$

Figure 9. Theoretical Combat Power and Actual Battle Results Ratios

In the preceding discussion, troop quality (Q) is noticeably absent in the theoretical combat power ratio. This omission is explained on the basis that the components of troop quality (leadership, morale, training, and chance/luck) are not directly measurable. However, battle outcomes are traditionally influenced by human factors. Therefore, some direct or indirect representation of these factors in combat models is both necessary and logical. For QJM to have military value, troop quality or, in a larger sense, unit combat effectiveness must be considered. This idea is discussed in the next subsection.

1. Determining Combat Effectiveness (CE)

Dupuy estimates troop quality or combat effectiveness by equating it to the actual battle results ratio divided by the theoretical combat power ratio. Since it is more

descriptive, the term **Combat Effectiveness (CE)** is used in lieu of Troop Quality (Q). Symbolically, combat effectiveness (CE) is defined by:

Combat Effectiveness (blue force): $$CE(b) = \frac{\dfrac{R(b)}{R(r)}}{\dfrac{P'(b)}{P'(r)}} = \left[\frac{R(b)}{R(r)} \times \frac{P'(r)}{P'(b)} \right]$$

Combat Effectiveness (red force): $$CE(r) = \frac{\dfrac{R(r)}{R(b)}}{\dfrac{P'(r)}{P'(b)}} = \left[\frac{R(r)}{R(b)} \times \frac{P'(b)}{P'(r)} \right]$$

Figure 10. Combat Effectiveness Equation

a. Reasonableness of the Combat Effectiveness Equation

Combat effectiveness (CE) in the QJM is intended to represent human characteristics such as leadership, morale, training, experience, and luck/chance. In order for a military force to command a combat effectiveness edge over its opponent, the following condition must be satisfied:

> *The force's actual battle results ratio must be greater than its theoretical combat power ratio. That is, the force's CE value must be greater than one.*

In the rare case that a force's actual battle results ratio equals its theoretical combat power ratio, the QJM defines the opponents to have equal combat effectiveness.

Does the above condition make military sense? Note that the QJM Combat Effectiveness equation consists of two ratios describing the same battle. The ratios R(b)/R(r) and P'(b)/P'(r) are not independant in the sense that changes in one affect the other. If a force is outnumbered in terms of personnel and weapons, yet manages to win or nearly win a battle, we would assume it is because the force is better trained, led, and motivated. The Combat Effectiveness equation reflects this conclusion by identifying a force's combat effectiveness to be equal to its actual battle results ratio times the reciprocal of its theoretical combat power ratio. Finally, the equations in Figure 10 show that combat effectiveness (CE) values for opposing forces are always reciprocals of each other.

The following example utilizes constructive data to illustrate the QJM's definition of combat effectiveness for a fictional battle.

Example 6

Step 1: THEORETICAL COMBAT POWER (P')

FACTOR	BLUE FORCE	RED FORCE
Force Strength (S)	500	1500
Operational/Environmental (OE)	2.5	1.0

Theoretical Combat Power values:

Blue Force: $P'(b) = S(b) \times OE(b) = 500 \times 2.5 = 1{,}250$

Red Force: $P'(r) = S(r) \times OE(r) = 1{,}500 \times 1.0 = 1{,}500$

Theoretical Combat Power Ratios:

Blue Force: $\frac{P'(b)}{P'(r)} = \frac{1{,}250}{1{,}500} = .83$

Red Force: $\frac{P'(r)}{P'(b)} = 1.2$

Discussion: The red force is theoretically more combat powerful than its blue opponent. Based on this advantage in firepower and personnel, should the red force be expected to win the battle? Step 2 shows what actually happened.

Step 2: ACTUAL BATTLE RESULTS (R)

FACTOR	BLUE FORCE	RED FORCE
Mission Accomplishment (M)	5	3
Ability to Gain or Hold Ground (G)	2.0	0.5
Effectiveness when Casualties are Incurred (C)	2.0	-1.0

Actual Battle Results values:

Blue Force: $R(b) = M(b) + G(b) + C(b) = 5 + 2.0 + 2.0 = 9.0$

Red Force: $R(r) = M(r) + G(r) + C(r) = 3 + 0.5 + (-1) = 2.5$

Actual Battle Results Ratios:

Blue Force: $\frac{R(b)}{R(r)} = \frac{9.0}{2.5} = 3.6$

Red Force: $\frac{R(r)}{R(b)} = .28$

Discussion: The actual battle results ratio reveals that the blue force won the engagement. Remarkably, the blue force was outmanned and outgunned.

One critical aspect of the ratio is the *relative size* of the factors M, G, and C. The larger a factor is, relative to the other factors, the greater its impact on determining R. For example by doubling each force's M factor while leaving the values for G and C constant, we obtain values for M(b) of 10 and M(r) of 6. These new values produce results ratios of 2.55 for the blue force R(b)/R(r) and .39 for the red force R(r)/R(b).

Example 6: Step 2 (continued)

On the other hand, by doubling the factor G while keeping the other factors at their original values, we obtain values for G(b) of 4 and G(r) of 1. These doubled values then produce results ratios of 3.66 and .27 for the blue and red forces respectively.

As a result of doubling each sides M factor, the blue force's results ratio decreased from 3.6 to 2.55 and the red force's results ratio increased from .28 to .39. When the relatively smaller G factor was doubled for each side, the results ratio for the blue force barely increased (3.6 to 3.66) and the results ratio for the red force decreased only slightly (.28 to .27).

This example shows that *the QJM actual battle results ratio is most sensitive to changes in its largest factor M.* In Step 3, combat effectiveness (CE) is computed using the data from our initial calculations.

Step 3: CALCULATING COMBAT EFFECTIVENESS (CE)

Blue Force:

$$CE(b) = \left[\frac{R(b)}{R(r)} \times \frac{P'(r)}{P'(b)} \right] = [3.6 \times 1.2] = 4.32$$

Red Force:

$$CE(r) = \left[\frac{R(r)}{R(b)} \times \frac{P'(b)}{P'(r)} \right] = [.28 \times .833] = .23$$

Discussion: In terms of numbers of personnel and weapons and operational/environmental factors, the blue force was weaker than its red adversary. Nonetheless, history shows that the blue force overcame this disadvantage to win the battle. As shown in the step 3 calculations, the answer to this discrepancy lies in the combat effectiveness of the respective forces. According to the QJM, the blue force is four times more combat effective than red. If this example represented an actual battle, then the blue force should be scrutinized in order to learn how its training, officer and enlisted leadership, tactics, and motivation contributed to outstanding combat effectiveness.

2. Determining Combat Power (P)

The final analytical stage in the QJM involves substituting the combat effectiveness component (CE) for the troop quality factor (Q) in the original Combat Power equation. This substitution results in the **Combat Power (P)** of a force which had engaged in historical combat. Symbolically, combat power is defined as:[5]

Combat Power (P): $P = S \times OE \times CE$

---

[5] It might be more accurate to write $P \simeq S \times OE \times CE$, since CE *approximates* Q in Clausewitz's equation for combat power. However, the QJM continues to use an equality (=) symbol.

Substituting from our previously defined expressions, the combat power (P) of the blue force is defined in the following figure:

$$P(b) = S(b) \times OE(b) \times CE(b)$$

$$= P'(b) \times CE(b)$$

where $P'(b) = S(b) \times OE(b)$

Equivalently:

$$P(b) = P'(b) \times \left[\frac{R(b)}{R(r)} \times \frac{P'(r)}{P'(b)} \right]$$

$$= \frac{R(b)}{R(r)} \times P'(r)$$

where $CE(b) = \left[\frac{R(b)}{R(r)} \times \frac{P'(r)}{P'(b)} \right]$

Figure 11. Combat Power Equations

To compute P(r), interchange subscripts (r) and (b) giving:

$$P(r) = P'(r) \times CE(r)$$

or equivalently,

$$P(r) = \frac{R(r)}{R(b)} \times P'(b).$$

a. Reasonableness of the Combat Power Equation

According to the QJM, the combat power of a military force is equal to its theoretical combat power times its combat effectiveness value. From a military standpoint, this relationship appears credible. The equation implies that true battlefield performance is a function of the number and type of weapons which a force possesses plus the fighting qualities of its personnel. Common sense supports QJM's declaration

that maximum performance on the battlefield requires not only a sufficient number of weapons but highly trained, well lead and motivated personnel to use them.

The second expression for combat power given by Figure 11 seems at first glance to be erroneous. It states that a force's combat power is equal to its actual battle results ratio times the theoretical combat power of its opponent. How can the QJM attempt to quantify a force's combat power without considering its weapons and personnel? Investigation of this issue, reveals that QJM includes each force's weapons and personnel (i.e. force strength (S)) in computing the actual battle results ratio. Specifically, force strength is included in the calculations for ability to gain or hold ground (G) and force effectiveness when casualties are incurred (C). These factors, ability to gain or hold ground (G) and force casualty effectiveness (C), are dissected and analyzed in the next chapter. The ensuing example demonstrates the process for computing combat power. To maintain continuity, the data of the previous example is used.

Example 7

COMBAT POWER (P)

Recall the calculations and data from the preceding example:

FACTOR	BLUE FORCE	RED FORCE
Force Strength (S)	500	1,500
Operational/environmental (OE)	2.5	1.0
Theoretical Combat Power (P')	1,250	1,500
Theoretical Combat Power Ratio (P'/P')	0.83	1.2
Actual Battle Results (R)	9.0	2.5
Actual Battle Results Ratio (R/R)	3.6	0.28
Combat Effectiveness (CE)	4.32	0.23

Combat Power Values:

Blue Force: $P(b) = P'(b) \times CE(b) = 1250 \times 4.32 = 5{,}400$

Red Force: $P(r) = P'(r) \times CE(r) = 1500 \times .23 = 345$

Discussion: The blue force possesses an overwhelming combat power advantage. Superior combat effectiveness of the blue force acts as a combat multiplier in its favor. Likewise, the red force's lack of combat effectiveness reduces its combat power potential.

3. The Combat Power Ratio

Historical combat is analyzed in the QJM by evaluating and manipulating the combat power ratio of opposing forces. Dupuy, in a private communication, defines the **Combat Power (P) Ratio** by:

$$\textbf{Combat Power Ratio (blue force):} \quad \frac{P(b)}{P(r)} = \frac{S(b) \times OE(b) \times CE(b)}{S(r) \times OE(r)}$$

$$\textbf{Combat Power Ratio (red force):} \quad \frac{P(r)}{P(b)} = \frac{S(r) \times OE(r) \times CE(r)}{S(b) \times OE(b)}$$

Figure 12. Combat Power Ratio

a. Reasonableness of the Combat Power Ratio

Assuming that $P = S \times OE \times CE$ still defines combat power, then the QJM combat power ratio seems to be incorrect. *The problem is that the denominator $S \times OE$ in Figure 12 is not equal to P, since P is defined differently in Figure 11.* Possibly, Dupuy intends the denominator P to be equal to theoretical combat power P'. However, if this is indeed Dupuy's desire, then the expression P(b)/P'(r) still does not make sense. Figure 13 shows mathematically that the expression P(b)/P'(r) simplifies to R(b)/R(r) and this is clearly not the intent of the model.

$$\frac{P(b)}{P'(r)} = \frac{S(b) \times OE(b) \times CE(b)}{S(r) \times OE(r)}$$

$$= \frac{P'(b) \times CE(b)}{P'(r)} \qquad \text{where } P' = S \times OE$$

$$= \frac{\left[P'(b) \times \dfrac{\frac{R(b)}{R(r)}}{\frac{P'(b)}{P'(r)}} \right]}{P'(r)} \qquad \text{where } CE(b) = \frac{\frac{R(b)}{R(r)}}{\frac{P'(b)}{P'(r)}}$$

$$= \frac{R(b)}{R(r)}$$

Figure 13. Combat Power Ratio Discrepancy

The preceding figure shows an inconsistency in the QJM combat power ratio. Substitution reveals that a force's combat power ratio is equal to its actual battle results ratio. However, these two ratios are in fact different. To further confuse matters, in his book *Understanding War*, Dupuy contradicts his Figure 12 equations when he includes each force's combat effectiveness (CE) value in the combat power ratio [Ref. 8: pp. 96,99-100,102]. To illustrate the problem just described, the following excerpts from *Understanding War* are provided in Figure 14 [Ref. 8]. Note that G denotes Germany, A denotes Allies, and terrain and posture factors are represented by OE. Additionally, in the reference, CEV is equivalent to CE.

Page 96 in *Understanding War*, defines the combat power ratio as:

$$\frac{P(G)}{P(A)} = \frac{S(G) \times OE(G) \times CE(G)}{S(A) \times OE(A) \times CE(A)}$$

Page 100 defines the combat power ratio for the Ardennes battle as:

$$\frac{P(G)}{P(A)} = \frac{1.712 \times 1 \times 1.2}{720 \times 1.82 \times 1.0} = 1.57$$

Figure 14. Combat Power as defined in 'Understanding War'

The excerpts in Figure 14 reveal a discrepancy regarding the QJM combat power ratio. The discrepancy concerns the CE values for the German and Allied forces. As previously discussed, opposing force CE values are always reciprocals of one another. If the Germans had a CE of 1.2, then the Allied CE should be .83 and not 1.

There are two possible interpretations of the inconsistencies in the QJM combat power ratio. They are:

1. If Dupuy desires to apply CE to only one side (let's assume the blue force) then he probably intends his combat power ratio to be:

$$\frac{P'(b)}{P'(r)} \times CE(b)$$

As Figure 13 shows, this expression reduces, through mathematical substitution, to R(b)/R(r). It is unlikely that this is Dupuy's motive, since we know that R(b)/R(r) is computed through entirely different means.

2. A second possible interpretation is that the rule of reciprocity for opposing force CE values is not being followed. This statement is borne out in Figure 14 where the German and Allied CE values are nonreciprocal.

The apparent inconsistencies in the combat power ratio, forced us to reexamine Dupuy's philosophy of how relative combat power should be expressed. Our first thoughts were to simply equate relative combat power to the ratio of opposing force Combat Power equations. Figure 15 contains our initial proposal for expressing relative combat power.

Combat Power Ratio (blue force): $$\frac{P(b)}{P(r)} = \frac{S(b) \times OE(b) \times CE(b)}{S(r) \times OE(r) \times CE(r)}$$

Combat Power Ratio (red force): $$\frac{P(r)}{P(b)} = \frac{S(r) \times OE(r) \times CE(r)}{S(b) \times OE(b) \times CE(b)}$$

Figure 15. Proposed Combat Power Ratio

The proposed combat power ratio includes each force's strength, operational environmental, and actual combat effectiveness values. We did recognize that a portion of the equation, CE(b)/CE(r) or CE(r)/CE(b), was a ratio of reciprocal values and thus would distort our final combat power ratio value. Still, we were curious to explore what results the proposed combat power ratio would provide. The next example uses the proposed form to compute a combat power ratio for opposing forces.

Example 8

From the previous two examples we obtained:

FACTOR	BLUE FORCE	RED FORCE
Force Strength (S)	500	1,500
Operational/environmental (OE)	2.5	1.0
Theoretical Combat Power (P')	1,250	1,500
Theoretical Combat Power Ratio (P'/P')	0.83	1.2
Actual Battle Results (R)	9.0	2.5
Actual Battle Results Ratio (R/R)	3.6	0.28
Combat Effectiveness (CE)	4.32	0.23

Proposed Combat Power Ratios:

Blue Force:

$$\frac{P(b)}{P(r)} = \frac{500 \times 2.5 \times 4.32}{1500 \times 1.0 \times .23} = 15.65$$

Red Force:

$$\frac{P(r)}{P(b)} = \frac{1500 \times 1.0 \times .23}{500 \times 2.5 \times 4.32} = .063$$

Discussion: For this fictional battle, the proposed combat power ratio reveals total relative combat power and fighting capabilities for opposing forces. In this example, the blue force's combat power ratio has ballooned to 15.65. Is this result reasonable? As previously stated, opposing force CE values are reciprocals of one another.

(continued on next page)

Example 8 (continued)

For the forces in this example, the division of opposing force CE values produces distortion factors of the following magnitudes:

$$\frac{4.32}{.23} = 18.8 \quad \text{and} \quad \frac{.23}{4.32} = .05$$

A combat power ratio for the blue force of 15.65 is not supported by the data. The blue force, though slightly less strong than its opponent, does possess a more than 4 to 1 CE edge. However, this advantage bears no resemblance to the overwhelming 15.65 value which the proposed ratio produced. Clearly, dividing by reciprocal CE values distorts our attempt to quantify this battle. *Therefore, our proposed combat power ratio seems unreasonable and not suitable for comparing forces of historical battles.*

In our search to identify a valid expression for relative combat power, we again considered Dupuy's attempt to apply CE to only one force at a time. We were beginning to feel confident that Dupuy wanted an expression for relative combat power of the following general form:

$$\frac{P'(b)}{P'(r)} \times CE(b) \text{ (raised to some power)}$$

We decided to first experiment with CE raised to the one-half power or, in other words, the square root of CE. Our proposed model took the following form:

$$\frac{P'(b)}{P'(r)} \times \sqrt{CE(b)}$$

Through substitution and simplification, the above expression reduced to a simple, yet remarkably profound quantity. We felt certain that we had hit upon the mysterious CE quantity which Dupuy had been searching for. The following figure shows what our proposed model simplifies to and we define this quantity as Relative Combat Power (RCP):

$$RCP(b) = \frac{S(b) \times OE(b) \times \sqrt{CE(b)}}{S(r) \times OE(r)}$$

$$= \frac{P'(b)}{P'(r)} \times \sqrt{CE(b)} \qquad \text{where } P' = S \times OE$$

$$= \frac{P'(b)}{P'(r)} \times \sqrt{\frac{R(b)}{R(r)} \times \frac{P'(r)}{P'(b)}} \qquad \text{where } CE(b) = \frac{R(b)}{R(r)} \times \frac{P'(r)}{P'(b)}$$

$$= \sqrt{\frac{R(b)}{R(r)} \times \frac{P'(b)}{P'(r)}}$$

Figure 16. Relative Combat Power Equation

The Relative Combat Power equation states that a force's combat power, relative to its opponent, is equal to the square root of its actual battle results ratio multiplied by its theoretical combat power ratio. In other words, relative combat power is a function of two quantities: the forces' *theoretical combat power* (weapons, environment, and military posture/readiness) and *actual combat performance* (results ratio). Using the combat data from Example 8, we calculate relative combat power (RCP) in the following example:

Example 9

From the previous example we obtain:

FACTOR	BLUE FORCE	RED FORCE
Force Strength (S)	500	1,500
Operational/environmental (OE)	2.5	1.0
Theoretical Combat Power (P')	1,250	1,500
Theoretical Combat Power Ratio (P'/P')	0.83	1.2
Actual Battle Results (R)	9.0	2.5
Actual Battle Results Ratio (R/R)	3.6	0.28
Combat Effectiveness (CE)	4.32	0.23

Relative Combat Power (RCP):

Blue Force: $$RCP(b) = \frac{S(b) \times OE(b) \times \sqrt{CE(b)}}{S(r) \times OE(r)} = \frac{500 \times 2.5 \times \sqrt{4.32}}{1500 \times 1} = 1.73$$

Red Force: $$RCP(r) = \frac{S(r) \times OE(r) \times \sqrt{CE(r)}}{S(b) \times OE(b)} = \frac{1500 \times 1 \times \sqrt{.23}}{500 \times 2.5} = .57$$

Discussion: The blue force possesses a relative combat power (RCP) value of 1.73, which means that, in this historic battle, the blue force was 1.73 times more combat powerful than its red opponent. This value is consistent with the combat data which revealed the blue force to be slightly inferior in theoretical combat power, but more than four times as combat effective. Likewise, the red force RCP is .57 and also in line with the combat data. *Finally, it should be noted that opposing force RCP values are reciprocals of one another.*

The Relative Combat Power (RCP) equation, appears to be the equation best suited to comparing the combat power of opposing forces in historic combat. We

examined the inconsistencies in the existing QJM combat power ratio and came to the conclusion that Dupuy was clearly on the right track when he wanted to apply CE to only one force at a time. Experimentation revealed that applying the square root of a force's CE to its theoretical combat power ratio would give us the relative combat power expression we were looking for. Additionally, we discovered that opposing force RCP values are reciprocals of one another.

4. Section Summary

This section has defined QJM's two basic submodels: the Actual Battle Results equation and the Combat Power equation. These equations are used to obtain the results ratio and combat power ratio for historic battles. The QJM combat power ratio appears to be algebraically incorrect and a Relative Combat Power equation has been offered as an alternative. Additionally, theoretical combat power (P′) is introduced and defined as a military force's strength (S) multiplied by its operational and environmental (OE) factors. A force's combat effectiveness (CE) is defined by the QJM as its actual battle results ratio divided by its theoretical battle results ratio. Three examples were used to illustrate how the QJM quantifies a combatant's combat effectiveness, combat power, and relative combat power.

In the next chapter the following combat factors used in the QJM are defined and examined for military reasonableness:

- mission accomplishment (M)
- force strength (S)
- ability to gain or hold ground (G)
- effectiveness when casualties are incurred (C)
- operational/environmental factors (OE)

IV. DECOMPOSITION OF QJM COMBAT FACTORS

A. A REVIEW OF KEY QJM RELATIONSHIPS

In the preceding chapter, the QJM was introduced and described. This chapter decomposes and analyzes the QJM combat factors mission accomplishment (M), force strength (S), ability to gain or hold ground (G), force effectiveness when casualties are incurred (C), and operational/environmental (OE) factors. Before analyzing these factors, let us review key QJM relationships. Recall that the Quantified Judgement Model uses two submodels to analyze historic combat.

Combat Power Equation: $P = S \times OE \times Q$

where:

P = combat power of the force
S = force strength (number and type of weapons plus personnel)
OE = operational/environmental
Q = quality of troops

and

Actual Battle Results Equation: $R = M + G + C$

where:

R = battle results of the force
M = mission accomplishment
G = ability to gain or hold ground
C = effectiveness when casualties are incurred

Figure 17. QJM Submodels

Both submodels are used to define ratios. These ratios allow actual battles to be analyzed both descriptively and theoretically. Using the example of blue (b) and red (r) adversaries, recall that the ratios are defined by:

$$\textbf{Theoretical Combat Power Ratio} \equiv \frac{P'(b)}{P'(r)} \quad \textbf{where} \quad P' = S \times OE$$

and

$$\textbf{Actual Battle Results Ratio} \equiv \frac{R(b)}{R(r)}$$

Figure 18. Theoretical Combat Power and Actual Battle Results Ratios

These ratios are then used to define combat effectiveness (CE) for military forces. Combat effectiveness (CE) in the QJM embodies the human fighting qualities of leadership, morale, training, chance/luck, and so forth. Since these intangibles are not directly measurable, the QJM defines CE as the differential between theoretical (what should have happened) and actual (what did happen) battle results. The QJM defines combat effectiveness (CE) by:

$$\textbf{Combat Effectiveness (blue force):} \quad CE(b) = \frac{\frac{R(b)}{R(r)}}{\frac{P'(b)}{P'(r)}} = \left[\frac{R(b)}{R(r)} \times \frac{P'(r)}{P'(b)} \right]$$

$$\textbf{Combat Effectiveness (red force):} \quad CE(r) = \frac{\frac{R(r)}{R(b)}}{\frac{P'(r)}{P'(b)}} = \left[\frac{R(r)}{R(b)} \times \frac{P'(b)}{P'(r)} \right]$$

Figure 19. Combat Effectiveness Equation

The final analytical stage in the QJM involves substituting the combat effectiveness component (CE) for the troop quality factor (Q) in the original Combat Power equation. This substitution results in the combat power (P) of a force which had engaged in historical combat. The combat power of a fighting force encompasses weapon lethality

(by type and number of weapons), military posture, terrain, weather, and human factors. The QJM defines combat power (P) by:

Combat Power (blue force): $P(b) = S(b) \times OE(b) \times CE(b)$

Combat Power (red force): $P(r) = S(r) \times OE(r) \times CE(r)$

Figure 20. Combat Power Equation

Historic battles are analyzed by using the combat power of combatants as ratios. *The combat power ratio is the QJM's primary measure for evaluating opposing forces.* A force which possesses a combat power ratio greater than one is the overall superior force. In Chapter 3, the QJM combat power ratio was found to be inconsistent with the definition of combat power for the blue and red forces. Thus a Relative Combat Power equation was derived in Chapter 3 and is defined by:

Relative Combat Power (blue force): $RCP(b) = \dfrac{S(b) \times OE(b) \times \sqrt{CE(b)}}{S(r) \times OE(r)}$

Relative Combat Power (red force): $RCP(r) = \dfrac{S(r) \times OE(r) \times \sqrt{CE(r)}}{S(b) \times OE(b)}$

Figure 21. Relative Combat Power Equation

B. DECOMPOSITION OF QJM COMBAT FACTORS

Up to this point in the thesis, the QJM combat factors have been introduced and described through numerous equations and examples. However, little emphasis has been placed on exploring how they are actually derived. In this section, the following QJM battlefield factors are defined and their derivations analyzed for reasonableness:

- mission accomplishment (M)
- force strength (S)
- ability to gain or hold ground (G)
- force effectiveness when casualties are incurred (C)
- operational/environmental (OE)

1. Mission Accomplishment (M)

The QJM describes mission accomplishment (M) as, "An expert judgement of the extent to which a force accomplished its assigned or perceived mission."[Ref. 8: p. 88] The QJM mission accomplishment values, scaled from one to ten, are presented in the succeeding figure.

Level of Mission Accomplishment	Variable Range (M)	Normal
Complete	7-10	8
Substantial/Relatively Satisfactory	5-7	6
Partial/Less than Satisfactory	3-5	4
Little Achievement	1-3	2

Figure 22. Levels of Mission Accomplishment

a. Reasonableness of the Mission Accomplishment Table

Mission accomplishment (M) is a subjective judgement based upon an individual's personal experiences and biases. Although subjective judgements are open to debate and prone to change, they are sometimes, as in the case of mission accomplishment (M), the only means of evaluation. Before choosing a mission accomplishment level, the decision maker should consider the relationship between the type of mission assigned and the force tasked to execute it. A well trained and led light infantry unit matched against armor or mechanized infantry is an example of an unreasonable mission assignment. To continue with this example, assume the infantry unit is defeated. A low mission accomplishment (M) value for the infantry unit leads to a lower battle results (R) value, which contributes to a lower combat effectiveness (CE) value. Consequently, an excellent unit (in this case our hypothetical light infantry unit) may not be, according to the QJM, highly combat effective. If the infantry unit is assigned a mission suited to its combat capabilities, it is likely to have a more realistic QJM combat effectiveness value. The preceding discussion emphasizes the importance of thorough research to ensure the assignment of appropriate M values.

2. Force Strength (S)

The QJM defines force strength (S) as the summation of weapon system lethality values, modified by environmental and operational factors, for eight major types of weapon systems [Ref. 9: p. 46]. The force strength (S) equation is shown in the following figure.

$$S(b) = \sum_{i=1}^{8} n_i(b) \times OLI_i(b) \times V_i(b)$$

Force Strength (blue force):

$$S(r) = \sum_{i=1}^{8} n_i(r) \times OLI_i(r) \times V_i(r)$$

Force Strength (red force):

where:

S = force strength

n = the number of weapons in a specific category (listed below)

OLI = Operational Lethality Index of a weapon system

V = weapon effects (terrain, weather, season, and air superiority)

i = the eight QJM weapon system categories (listed below)

1 = small arms

2 = machine guns

3 = heavy weapons

4 = anti-armor

5 = artillery

6 = air defense

7 = armor

8 = close air support

Figure 23. Force Strength Equation

a. Reasonableness of the Force Strength Equation

Force strength (S) is a function of three components: number of weapons, lethality of weapons, and weapon modifying factors. The first component, number of weapons (n), is simply the quantity of weapons (by category) which a force possesses. The second component, weapon lethality, is defined in [Ref. 9: p. 19] as:

> The inherent capability of a given weapon system to kill personnel, or to make material ineffective in a given period of time, where capability includes the factors of weapon range, rate of fire, accuracy, radius of effects, and battlefield mobility.

The QJM uses Operational Lethality Indices (OLI's) to quantify weapon effectiveness. OLI's consider such weapon characteristics as rate of fire, number of potential targets per strike, reliability, accuracy, range and so forth [Ref. 9: p. 27]. Where needed, Dupuy and associates have developed formulae to quantify specific weapon characteristics. All relevant QJM weapon characteristics, plus weapon dispersion factors, are combined through addition, multiplication and division to form the OLI's of weapons in the eight categories.

The third and final component, weapon effects, is composed of factors such as terrain, weather, season, and air superiority [Ref. 9: pp. 228-230]. Weapon effects (V), for each of the eight weapon system categories, *is the product* of either one, two, three or four factors (terrain, weather, season, and air superiority). The rules for determining which factors go with a particular weapon system category are found in [Ref 9: p. 46]. Again, when V is actually calculated for one of the eight weapon system categories, these factors are multiplied together rather than being additive. Finally, *the reader should be aware that V and OE are not independant. That is, they share some common factors such as terrain, weather, and season.*

The QJM incorporates the three components (n, OLI, and V) into the Force Strength equation to determine S. The Force Strength (S) equation is illuminated through the following simple example.

Example 1

WEAPON TYPE	NUMBER (n)	OLI	WEAPON EFFECTS (V)
M-16	30	0.35	0.8 (terrain: flat, heavily wooded)
Machine gun	5	1.0	0.8 (terrain: flat, heavily wooded)
TOW	3	176	0.8 (terrain: flat, heavily wooded)
M-60 tank	2	797	0.8 (terrain: flat, heavily wooded) and 0.5 (weather: wet, heavy, temperate)

Force Strength (S):

$$S = (30)(.35)(.8) + (5)(1)(.8) + (3)(176)(.8) + (2)(797)(.8)(.5) = 1072.4$$

Discussion: The small force in this example possesses a strength value of 1072.4. The force operates in flat heavily wooded terrain during periods of heavy rain. In this example, all four weapon types are affected by terrain, but only the tank is affected by the weather factor.

What happens to the force, described in Example 1, when it operates in different terrain and weather conditions? For example, suppose the force operates in flat, hard, and bare terrain. The weather conditions are ideal: temperate, sunshine, and dry. These conditions are more favorable to the force than those in Example 1. Therefore, we should expect the force to possess an equal or greater force strength value (S). Example 2 reveals the force's strength when it operates in these new circumstances.

Example 2

WEAPON TYPE	NUMBER (n)	OLI	WEAPON EFFECTS (V)
M-16	30	0.35	1.0 (terrain: flat, bare, and hard)
Machine gun	5	1.0	1.0 (terrain: flat, bare, and hard)
TOW	3	176	1.0 (terrain: flat, bare, and hard)
M-60 tank	2	797	1.0 (terrain: flat, bare, and hard)
			and
			1.0 (weather: temperate, dry, sunshine)

Force Strength (S):

$$S = (30)(.35)(1) + (5)(1)(1) + (3)(176)(1) + (2)(797)(1)(1) = 2137.5$$

Discussion: The military force is stronger in a more favorable environment. Consequently, the force's strength value (S) has increased from 1072.4 to 2137.5.

These two examples, 1 and 2, show the QJM strength equation to be reasonable from a common sense perspective. To further test the reasonableness of the strength equations, let's explore what happens to force strength in a severely degraded environment. In other words, what happens to the same force when it fights in harsh terrain and poor weather. If the force fights in rugged, heavily wooded terrain during extremely cold wet weather conditions, what happens to its force strength? The next example computes S for these terrain and weather conditions.

Example 3

WEAPON TYPE	NUMBER (n)	OLI	WEAPON EFFECTS (V)
M-16	30	0.35	0.6 (terrain: rugged, heavily wooded)
Machine gun	5	1.0	0.6 (terrain: rugged, heavily wooded)
TOW	3	176	0.6 (terrain: rugged, heavily wooded)
M-60 tank	2	797	0.6 (terrain: rugged, heavily wooded) and 0.5 (weather: wet, heavy, extreme cold)

Force Strength (S):

$$S = (30)(.35)(.6) + (5)(1)(.6) + (3)(176)(.6) + (2)(797)(.6)(.5) = 804.3$$

Discussion: This example further reinforces the reasonableness of the QJM Strength equation. This and the previous two examples show that weapons by themselves are not the ultimate indicators of military force strength. Rather, environmental (terrain, weather, and season) and operational (air superiority) factors act to either increase or decrease weapon capabilities.

3. Ability to Gain or Hold Ground (G)

The ability to gain or hold ground factor (G) is described as, "A value representing the extent to which a force was able to gain or hold ground." [Ref. 8: p. 88] Dupuy and associates mathematically define G by:

Ability to Gain or Hold Ground (blue force):

$$G(b) = \sqrt{\frac{S(r)}{3S(b)} \times \frac{POS(r)}{POS(b)} \times \frac{(4D(r) + A(r))}{A(b)}}$$

Ability to gain or hold ground (red force):

$$G(r) = \sqrt{\frac{S(b)}{3S(r)} \times \frac{POS(b)}{POS(r)} \times \frac{(4D(b) + A(b))}{A(r)}}$$

where:

G = ability of force to gain or hold ground

S = force strength

D = average daily distance of advance or withdrawl for forces in contact (positive for advancing force, negative for withdrawing force)

A = depth of area occupied by the force

POS = military posture of the force (listed below)

Posture	Value (POS)
Attack	1.0
Defense (hasty)	1.3
Defense (prepared)	1.5
Defense (fortified)	1.6
Withdrawal	1.15
Delay	1.2

Figure 24. Ability to Gain or Hold Ground Equation

a. Reasonableness of the Ability to Gain or Hold Ground Equation

The Ability to Gain or Hold Ground equation, [Ref. 9: p. 48], **does not** appear reasonable from a military standpoint. In battle, military forces strive to either gain (offense) or hold ground (defense) and thereby *maximize* their respective G factors. Unfortunately, the equation does not reflect a force's desire to maximize G. For instance, examining the equation for G(b) we see that as the blue force (b) increases its strength, its value for G(b) decreases. Similarly, as a force increases its defensive posture,

its G factor also decreases. The numbers in the equation, three and four, appear to be adjustment factors but their significance and the reason for these particular values, is not known. The subsequent example uses constructive data to illustrate the unsuitability of the Ability to Gain or Hold Ground equation.

Example 4

FACTOR	BLUE FORCE	RED FORCE
Force Strength (S)	50,000	20,000
Military Posture (POS)	1.0	1.6
Depth of Area (A)	11 km	7 km
Average Daily Advance or Withdrawal Distance (D)	+1 km	-1 km

Ability to Gain or Hold Ground (G):

Blue Force:

$$G(b) = \sqrt{\frac{20,000}{3(50,000)} \times \frac{1.6}{1} \times \frac{(4(-1) + 7)}{11}} = .241$$

Red Force:

$$G(r) = \sqrt{\frac{50,000}{3(20,000)} \times \frac{1}{1.6} \times \frac{(4(+1) + 11)}{7}} = 1.05$$

Discussion: A subscript is not assigned to the equation's D variable in (Ref. 9: p. 48). As shown in Figure 24, the assumption is made that D(r) goes with the G(b) equation and D(b) to the G(r) equation.

The Ability to Gain or Hold Ground equation shows the red force to be more than four times as effective as blue in either gaining or holding ground. Do these results make military sense? The combat data shows the blue force to possess an overwhelming advantage in force strength (S). Additionally, the blue force was able to advance, on average, one kilometer per day against red defenses. In view of these facts, the Ability to Gain or Hold Ground equation seems questionable. Logic supports the argument that the blue force should not be four times less effective as red in this area.

If the blue force's strength is doubled to 100,000, its depth of area increased to 16 kilometers and all other factors held constant, what would be the result? Since the blue force is now 100 percent stronger, common sense suggests that its ability to gain or hold ground should improve. The following results are obtained when the blue force's strength (S) and depth of area (A) are increased to 100,000 and 16 kilometers respectively.

Blue Force: $$G(b) = \sqrt{\frac{20{,}000}{3(100{,}000)} \times \frac{1.6}{1} \times \frac{(4(-1)+7)}{16}} = .141$$

Red Force: $$G(r) = \sqrt{\frac{3(100{,}000)}{20{,}000} \times \frac{1}{1.6} \times \frac{(4(+1)+16)}{7}} = 5.17$$

Discussion: This example illustrates the inadequacy of the Ability to Gain or Hold Ground equation. The blue force has increased its strength (by 100 percent) while red's strength has remained constant. In spite of the blue force's strength increase, its value for G(b) has decreased from .241 to .141.

To improve the Ability to Gain or Hold Ground equation, the following **modified** equation is offered as an alternative.

Blue Force: $$G(b) = \sqrt{\frac{S(b)}{S(r)} \times \frac{POS(b)}{POS(r)} \times \frac{(4D(b) + A(b))}{A(r)}}$$

Red Force: $$G(r) = \sqrt{\frac{S(r)}{S(b)} \times \frac{POS(r)}{POS(b)} \times \frac{(4D(r) + A(r))}{A(b)}}$$

Figure 25. Modified Ability to Gain or Hold Ground Equation

The modified Ability to Gain or Hold Ground equation is used in the next example. To assist in comparing both equations (QJM and modified), the data from Example 4 is used.

Example 5

FACTOR	BLUE FORCE	RED FORCE
S	50,000	20,000
POS	1.0	1.6
A	11 km	7 km
D	+1 km	-1 km

Blue Force: $$G(b) = \sqrt{\frac{50{,}000}{20{,}000} \times \frac{1}{1.6} \times \frac{(4(+1) + 11)}{7}} = 1.82$$

Red Force: $$G(r) = \sqrt{\frac{20{,}000}{50{,}000} \times \frac{1.6}{1} \times \frac{(4(-1) + 7)}{11}} = .417$$

Discussion: The modified equation reveals the blue force to be superior in gaining or holding ground. These results seem reasonable when the red force's strength and daily advance rate advantages are considered. Let's now examine (as we did in Example 4) what happens to G when the blue force's strength is doubled to 100,000 and its depth of area increased to 16 kilometers.

$$\text{Blue Force:} \quad G(b) = \sqrt{\frac{100,000}{20,000} \times \frac{1}{1.6} \times \frac{(4(+1) + 16)}{7}} = 2.98$$

$$\text{Red Force:} \quad G(r) = \sqrt{\frac{20,000}{100,000} \times \frac{1.6}{1} \times \frac{(4(-1) + 7)}{16}} = .244$$

Discussion: Logically, the blue force's G value has increased to 2.98 when both its strength and depth of area increased. Example 5 provides strong evidence that the modified Ability to Gain or Hold Ground equation is militarily more reasonable than the present QJM version.

4. Effectiveness when Casualties are Incurred (C)

The effectiveness when casualties are incurred factor (C) is described as, "A value representing the efficiency of the force in terms of casualties, taking into consideration the strengths of the two sides and the casualties incurred by both sides." [Ref. 8: p. 88] The QJM [Ref. 9: p. 49] defines C by:

Effectiveness when Casualties are Incurred (blue force):

$$C(b) = (VL(r))^2 \times \left[\sqrt{\frac{CAS(r)}{CAS(b)} \times \frac{POS(b)}{POS(r)} \times \frac{S(b)}{S(r)}} - 10\sqrt{\frac{CAS(b)}{N(b)}} \right]$$

Effectiveness when Casualties are Incurred (red force):

$$C(r) = (VL(b))^2 \times \left[\sqrt{\frac{CAS(b)}{CAS(r)} \times \frac{POS(r)}{POS(b)} \times \frac{S(r)}{S(b)}} - 10\sqrt{\frac{CAS(r)}{N(r)}} \right]$$

where:

C = effectiveness of force when it incurs casualties

VL = vulnerability of the force to hostile firepower (see Figure 27)

CAS = average daily number of casualties

POS = military posture of the force. (see Figure 24)

S = force strength

N = total number of personnel in the force

Figure 26. Effectiveness when Casualties are Incurred Equation

Figure 27 defines the QJM Vulnerability equation. The vulnerability factors POSV, AIRV, AMPHV, and TD are listed in [Ref. 9: pp. 228,230,231] using the notation u_v, v_y, v_r, and r_u.

Vulnerability (blue force):

$$VL(b) = 1 - \left[\frac{N(b) \times POSV(b) \times (S(r))^{.5} \times AIRV(b) \times AMPHV(b)}{TD(b) \times (S(b))^{1.5}} \right]$$

Vulnerability (red force):

$$VL(r) = 1 - \left[\frac{N(r) \times POSV(r) \times (S(b))^{.5} \times AIRV(r) \times AMPHV(r)}{TD(r) \times (S(r))^{1.5}} \right]$$

where:

VL = vulnerability of the force to hostile firepower

N = number of personnel in force

POSV = posture vulnerability of force

AIRV = vulnerability due to air status

AMPHV = vulnerability during amphibious operations or river crossings

TD = terrain factor when force is in the defense

S = force strength

Figure 27. Vulnerability Equation

a. Reasonableness of Effectiveness when Casualties Incurred Equation

The Effectiveness when Casualties are Incurred equation seems reasonable from a military standpoint. The equation states that a force's effectiveness (in terms of operating with casualties) is a function of its opponents vulnerability and casualty ratio, its own posture and strength ratios, and the proportion of its casualties to total personnel. According to the equation, a force becomes increasingly effective as its opponent becomes more vulnerable, suffers more casualties and decreases in strength. Similarly, a force increases its effectiveness as it improves its defensive posture and suffers fewer casualties.

The next example illustrates the use of the Effectiveness when Casualties are Incurred equation. The example data is constructive and intended solely for demonstration.

Example 6

FACTOR	BLUE FORCE	RED FORCE
Force Strength (S)	50,000	20,000
Number of Personnel (N)	1,200	800
Average Daily Number of Casualties (CAS)	60	40
Vulnerability to Hostile Firepower (VL)	0.85	0.6
Military Posture (POS)	1.0	1.6

Blue Force: $$C(b) = (.6)^2 \times \left[\sqrt{\frac{40}{60} \times \frac{1}{1.6} \times \frac{50,000}{20,000}} - 10\sqrt{\frac{60}{1,200}} \right] = -1.86$$

Red Force: $$C(r) = (.85)^2 \times \left[\sqrt{\frac{60}{40} \times \frac{1.6}{1} \times \frac{20,000}{50,000}} - 10\sqrt{\frac{40}{800}} \right] = -1.53$$

Discussion: Both forces possess negative values for C. The red force, though, is more effective (in terms of operating with casualties) and has a C value of -1.53. Is this result to be expected? Even though the blue force holds a strength and personnel edge, its high vulnerability value increases red force effectiveness. Likewise, its low posture value reduces its own effectiveness.

If the blue force (of Example 6) increases its strength (S) and personnel by 50 percent and all other factors remain constant, what should happen to the values C(b) and C(r)? The following example calculates C(b) and C(r) for a 50 percent increase in blue strength and personnel.

Example 7

FACTOR	BLUE FORCE	RED FORCE
S	75,000	20,000
N	1,800	800
CAS	60	40
VL	0.85	0.6
POS	1.0	1.6

Blue Force: $$C(b) = (.6)^2 \times \left[\sqrt{\frac{40}{60} \times \frac{1}{1.6} \times \frac{75,000}{20,000}} - 10\sqrt{\frac{60}{1,800}} \right] = -1.37$$

Red Force: $$C(r) = (.85)^2 \times \left[\sqrt{\frac{60}{40} \times \frac{1.6}{1} \times \frac{20,000}{75,000}} - 10\sqrt{\frac{40}{800}} \right] = -1.65$$

Discussion: The blue force's ability to operate with casualties has improved relative to the red force. A 50 percent increase in strength and personnel has raised C(b) from -1.86 to -1.37. This result appears reasonable and reinforces the credibility of the Effectiveness when Casualties are Incurred equation.

5. Operational and Environmental Factors (OE)

The final QJM combat factor is operational/environmental (OE) which is described as: "The variable factors reflecting the combat circumstances affecting the *force.*" [Ref. 8: p. 81] The QJM OE factors are mobility, posture, vulnerability, fatigue, surprise, air superiority, terrain, weather, and season [Ref. 8: p. 87].

a. Reasonableness of the Operational and Environmental Factors

At this juncture, the reader may recall that force strength (S) incorporates several of the OE factors (terrain, weather, season, and air superiority) under the name weapon effects (V). However, weapon effect factors (V) are applied only to specific weapon systems, whereas OE factors are applied to entire forces. The OE factors, with the exception of fatigue, are quantified through table lookups and formulae [Ref. 9: p. 33].

The following example illustrates how the OE factors are employed in the QJM. The example data is for a hypothetical battle.

Example 8

OE FACTOR	NOTATION	VALUE
terrain	TD	1.5
weather	w	0.9
season	se	1.1
mobility	mo	1.1
posture	POS	1.3
vulnerability	VL	0.6

Calculation of Operational/Environmental (OE):

$$OE = TD \times w \times se \times mo \times POS \times V = 1.5 \times .9 \times 1.1 \times 1.1 \times 1.3 \times .6 = 1.27$$

Discussion: The QJM OE factor is 1.27. This value (OE = 1.27) is used in the Combat Power equation $P = S \times OE \times CE$ to obtain P. The OE, along with CE, acts as a proportionality constant in the Combat Power equation by modifying the effects of weapons.

C. SUMMARY

The objective of the chapter was to determine if the QJM equations are reasonable and if they adequately and accurately represent historic ground combat. The QJM equations and their components (termed factors) were analyzed for reasonableness and are summarized as follows:

1. Summary of the QJM Equations

- **Actual Battle Results Equation (R):** R acts as a report card which grades adversaries, after the battle, in three categories (or factors) M, G, and C. The equation is reasonable, since the concept of additivity supports the contention that forces strive to maximize R.

- **Theoretical Combat Power Equation (P′):** Theoretical combat power (P′) is proportional to force strength (S). The factor OE is the proportionality constant. P′ quantifies the combat potential of a force in weapons (type and number) and

operational environmental factors. Moreover, P′ intentionally omits human factors. The Theoretical Combat Power equation appears militarily reasonable.

- **Actual Battle Results Ratio R(b)/R(r):** The ratio is reasonable. The winning force on the battlefield possesses a ratio greater than one. Likewise, the losing force possesses a ratio of less than one.

- **Theoretical Combat Power Ratio P′(b)/P′(r):** The ratio compares adversaries in terms of force strength and operational/environmental factors and omits human qualities (leadership, morale, training and so forth). The ratio is reasonable because it reveals the theoretically superior force.

- **Combat Effectiveness Equation (CE):** The CE equation is defined as a force's actual battle results ratio divided by its theoretical combat power ratio. The equation is reasonable and states that forces' hold CE edges only when their actual battle results ratio is greater than their theoretical combat power ratio.

- **Combat Power Equation (P):** P is equal to the product of three factors S, OE, and CE. A force's combat power in historic combat is a function of its type and number of weapons, environment, operational factors, and the fighting qualities of its personnel. From a military standpoint, the equation appears reasonable.

- **Relative Combat Power Equation (RCP):** The QJM combat power ratio is algebraically inconsistent. Therefore, a Relative Combat Power equation was derived to more accurately represent historic ground combat between opposing forces.

2. Summary of the QJM Factors (M, S, G, C, and OE)

- **Mission Accomplishment (M):** M, an integer, is scaled from one to ten and determined subjectively. The approach for obtaining M is reasonable. Finally, the QJM Actual Battle Results equation, $R = M + G + C$, appears most sensitive to changes in M.

- **Force Strength (S):** S is a function of three components: number and type of weapons, weapon lethality, and operational/environmental factors. The QJM Force Strength equation is reasonable from a military perspective.

- **Ability to Gain or Hold Ground (G):** The equation used to compute G is not reasonable. A modified equation has been offered as an alternative.

- **Effectiveness when Casualties are Incurred (C):** C, a dimensionless quantity, is a function of casualties, military posture, force strength, force vulnerability, and number of personnel. The Effectiveness when Casualties are Incurred equation seems reasonable.

- **Operational and Environmental Factors (OE):** The OE factors comprise mobility, posture, vulnerability, fatigue, surprise, air superiority, terrain, weather, and season. These factors are applied to entire forces and are militarily reasonable.

V. CONCLUSIONS AND FUTURE DIRECTIONS

A. CONCLUSIONS

There are numerous techniques or methodologies for analyzing land combat and they appear to fall into two major categories: qualitative analyses and quantitative analyses. The thesis has focused on one methodology in the second category called the Quantified Judgement Model (QJM). The QJM is used to examine past battles or predict future battle outcomes. The thesis, however, focuses exclusively on describing the QJM and applying it to historic ground combat.

The QJM is composed of two submodels whose interactions manifest such battlefield intangibles as leadership, training, morale, experience, and chance/luck. The thesis tests the reasonableness of those submodels and investigates their sensitivity to changes in the model parameters.

Exploration of the QJM's equations and their components (termed factors) revealed that the model is generally sound and reasonable. However, the QJM combat power ratio was found to be algebraically incorrect and a Relative Combat Power (RCP) equation was derived to replace it. The RCP equation is defined as follows:

Blue Force: $$RCP(b) = \frac{P'(b)}{P'(r)} \times \sqrt{CE(b)}$$

Red Force: $$RCP(r) = \frac{P'(r)}{P'(b)} \times \sqrt{CE(r)}$$

where:

b = blue force

r = red force

P′ = theoretical combat power

CE = combat effectiveness

Figure 28. Relative Combat Power Equation

Additionally, the Ability to Gain or Hold Ground equation seemed unreasonable from a military standpoint and a modified equation was again offered as a possible substitute.

What are the practical military applications of the model? In the first place, a mathematically correct QJM could be used to analyze the performance of combat units in training exercises and actual combat operations. For example, several U.S. Marine infantry battalions could be matched, one at a time, against a specific adversary to accomplish a specific mission. Each battalion could be looked at by the QJM in terms of how they fought against that same opponent. Though each of the battalions are similar in numbers of personnel and weapons, we should expect differences in their performance. The QJM may help to identify unusually successful units, which could then be studied to learn what makes them so effective.

The QJM is a novel approach to exploring historic ground combat. Trevor Dupuy deserves great credit for his pioneering efforts and original thought. With additional mathematical refinement and verification, the QJM should prove to be a useful model for studying combat.

B. FUTURE DIRECTIONS

The following topics concerning the QJM are highly recommended for future research:

- That the Force Strength (S) equation undergo a thorough dimensional analysis for reasonableness.
- That the QJM's secondary equations (such as, vulnerability, mobility, range factor, punishment factor and so forth) also be tested for reasonableness and that they undergo a thorough dimensional analysis [Ref. 9].
- That specific factors (such as, terrain, weather, and season) are applied twice to individual forces (once to the entire force and then again to the eight individual weapon types). This double counting should be examined for reasonableness.
- That the tabular QJM factors also be tested for reasonableness (to include alternative scaling techniques) and sensitivity [Ref. 9: pp. 228-231].
- That a readable QJM Users Manual be developed for military analysts desiring to study historic ground combat.
- That a well documented military operation (such as, the U.S. invasion of Grenada) be analyzed through the QJM and the results tested for reasonableness.

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